Study on the Effect of Structural Parameters for Safety Performance of Cable Barrier

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Abstract

With the numerical modeling method, the effect of three parameters, which are the spacing of the stand column, the initial tension and the installation length in the structure of the cable barrier, on its safety performance was analyzed in this paper. Research suggests the effect of the spacing of the stand column on the cable barrier is significant. When the initial installation tension and the installation length are determined, and its spacing of the stand column is 6 m, the safety performance of the barrier structure is relatively superior. In the case that the clear width of the roadside meets the requirement, it is reasonable that the initial tension of the cable barrier is between 30 kN and 35 kN. For the installation length, above a certain installation length, the effect of its change is relatively small. Analytical results can be referred by the design.

Keywords

Cable Barrier; Initial Tension; Spacing of the Stand Column; Installation Length; Numerical Modelling

Introduction

The flexible barrier is a kind of barrier with relatively strong buffering capacity, which is another extreme style corresponding with the rigid barrier. The cable barrier is a main representative of flexible barriers, which is formed by several cables with initial tension that are fixed on the stand column, and it resists crash from cars and absorbs collision energy by tensile stress of cables. Cables work in the elastic range so that they seldom need to be replaced. The barriers are artistic, creating little oppressive feeling for drivers, but when middle stand columns were destroyed, the amount of maintenance work would be huge, so most of them are applied at places with relatively high requirement for the environmental quality. Nowadays, the cable barrier is coming into use in abroad, and undeniably, three parameters which are the spacing of the stand column, the initial tension and the installation length in its structure may influence its crash safety; however, there is no reference for the determination of the three parameters (Ministry of Communications of the People's Republic of China, 2004, 2006; People's Communications Press, 2002). In this paper, the numerical modeling method was adopted to study the effect of these three parameters on the safety of the cable barrier and analyze its influence rules, in order to provide references for design of this barrier (Sun Yuechang, 1996; Xu Liuqing, 2003).

Modelling

Finite element software, LS-DYNA, was used to do the numerical modeling to the car-cable barrier crash system. LS-DYNA is an element of ANSYS and one of the most famous explicit dynamic analysis programs in the world (ANSYS Ltd, 2003).

Determination of the Material Model

The crash system is composed by five parts, which are the stand column, the prevention block, the cable, the bolt and the car, and four material models need to be determined: the material model of the car, the material model of the stand column and the prevention block, the material model of the cable and the material model of the bolt.

The *MAT_PLASTIC_KINEMATIC model, which is isotropic model, or kinematic hardening model, or the mix model of isotropy and kinematic hardening, was adopted as the stand column and the prevention block material model. This model is related to strain rate, and failures can be considered. *MAT_CABLE_DISCRETE_BEAM model, in which the element material can merely bear the tension, was adopted for the cable.

The rigid element was adopted for the bolt. For the material of the car, since the overall effect was merely considered for the analysis of the car, the rigid material model was adopted in this paper, in which the density is obtained by the equivalent conversion under the principle that the mass equals to that of the

real car.

Determination of the Car

According to related materials, if the mass of the model is 10 t, the crash velocity is 80 km/h, the crash angle can be determined to be 20° (Liu Shaoyuan, 1995), and the entity unit is adopted to divide the rigid body, and its density is obtained by the division of the actual crash mass by the volume of the rigid body in the limited element model. However, here its value is 55712 kg/m^3, and values of other actual constants are in the following table.

TABLE 1 THE PARAMETERS USED IN ANALYSIS

Name of component	Stop block	Upright column	Hawser
Thickness(mm)	3	4	-
Shear factor	5/6	5/6	1
Unit volume constant (mm^3)	-	-	26500
Elasticity modulus(MPa)	210000	210000	140000
Accumulated points	5	5	4
Tangent modulus (MPa)	2100	2100	-
Yield stress (MPa)	235	235	120
Density(kg/m^3)	7890	7890	8130

The Analysis Procedure

The effect of three parameters, which are the spacing of the stand column, the initial tension and the installation length in the structure of the cable barrier, on its safety performance was analyzed. In the analysis, two of them were set as constants, while one of three parameters was considered to be changed. The initial status was calculated: the spacing of the stand column was 5 m, and the initial tension was 20 kN, and installation length was 84 m, and the breakdown tension of the cable was 160.8 kN.

Effect of the Initial Tension on the Safety Performance

By varying the initial tension of the barrier structure, the factors that influence the safety performance of the cable barrier were analyzed. Here five cases of the initial tension, which were 20 kN, 25 kN, 30 kN, 35 kN, 40 kN, were calculated.

1) *Contrast of Maximum Dynamic Deformations*

The extremums of dynamic deformations under different initial tensions were shown in Fig. 1. For cars out of control, as long as the central position did not pass the initial installation position of the barrier, cars would not turn out the road due to the unbalancing of the center of gravity. However, the width of most large cars passes 2.4 m; hence, 1.2 m is the extremum of dynamic deformations of the barrier, and 20 kN initial tension does not meet the requirement. Four other cases were analyzed as follows.

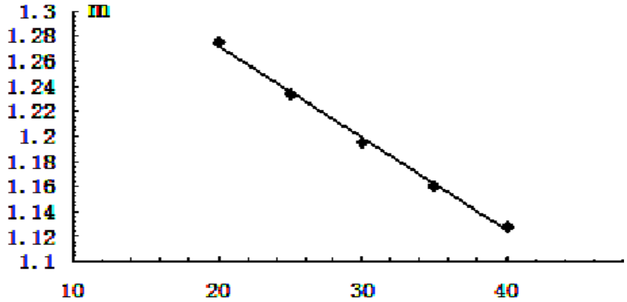

FIG. 1 THE TREND CURVE OF DYNAMIC DEFORMATION EXTREME UNDER DIFFERENT INITIAL TENSION

2) *Contrast Of The Accelerated Speed*

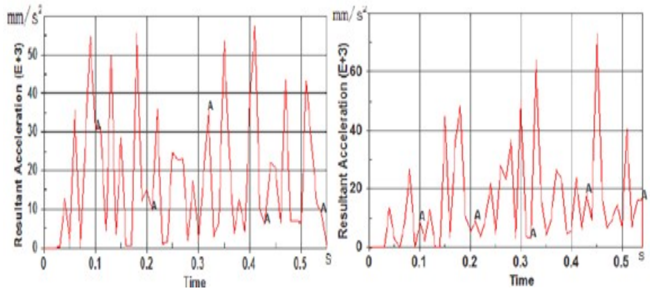

FIG. 2 THE ACCELERATION HISTORY CURVE FOR 25 KN, 30 KN INITIAL TENSION RESPECTIVELY

Through analysis it is found that the initial tension corresponded with the extremum of the accelerated speed varies closely linearly. Each time the initial tension increases 5 kN, the maximum instantaneous accelerated speed increases about 1 g, and when the initial tension is 40 kN, the maximum value reaches 92.3 m/s, which equals to 9.42 g, which is very harmful to passengers. When analysing the time-distance graph of the accelerated speed under different initial tensions it is found that, when 25 kN, the frequency when the extremum of the accelerated speed of the barrier appears is relatively high, and when 40 kN, the instantaneous maximum is relatively large. It can be seen that, the initial tension under 30 kN~35 kN is relatively appropriate.

3) *Contrast of the Contact Force*

By comparing the time-distance curve of the contact force, it is found that, the change of its shape is not large, but with the increase of the

initial tension, the range ability of the extremum of the contact force decreases gradually. Compared to that under 25 kN, that under 40 kN increases about 8.2%. For cars and passengers, it is harmful that the larger contact force is, the more serious damage to cars, and the more harmful damage to passengers.

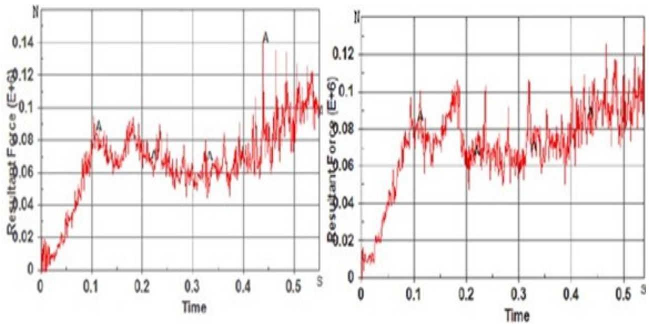

FIG. 3 THE CONTACT FORCE HISTORY FIGURE WHEN 25 KN, 40 KN INITIAL TENSION RESPECTIVELY

To sum up, for the cable barrier-car crash system, if dynamic deformation is as the standard, all barrier forms with initial tension larger than 25 kN can meet the safety requirement.

Nevertheless, as the traffic safety facility, the function of the barrier is not only ensuring the safety of cars, but also furthest considering the safety of passengers. Accordingly, in consideration of every performance of the barrier during the crash process comprehensively, it is suggested in this paper that the structural form while the initial tension of the cable barrier is 30 kN~35 kN is appropriate, which is most beneficial to the safety of passengers in the case of crash.

Effect of the Spacing of the Stand Column on the Crash Safety Performance

By the analysis of the initial tension, the initial tension being proposed to be 30 kN, and the installation length being unchanged as 84 m, every safety performance of the barrier of 5 m, 6 m and 7 m spacing of the stand column was compared.

1) Contrast Analysis of the Maximum Dynamic Deformation

It is found in the analysis that, the maximum dynamic deformation of the cable barrier is extremely sensitive to the parameter, the spacing of the stand column. With the increase of the spacing of the stand column, the extremum of the dynamic deformation increases remarkably, and that under 5 m, 7 m are 1.113 m, 1.274 m respectively.

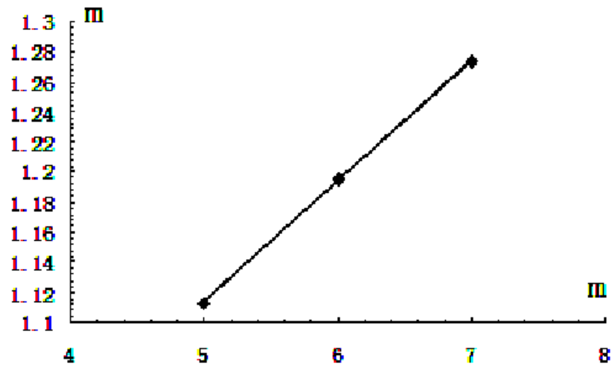

FIG. 4 THE DYNAMIC DEFORMATION EXTREMES CURVE OF DIFFERENT COLUMNS SPACING

2) Contrast Analysis of the Accelerated Speed

As shown in Fig. 5, the difference of the instantaneous maximum values under 5 m spacing and 7 m spacing is not large, which are 75.96 m/s² and 76.03 m/s², and the maximum value under 6 m spacing is 71.95 m/s². However, when the spacing is 5 m, the frequency that the extremum of the curve appears is relatively high, which means the damage suffered by passengers during the crash is larger. By analysing the relationship between the extremum of the accelerated speed and the spacing of the stand column, it is found that it is close to a parabola. It is seen that, 6 m spacing is more appropriate.

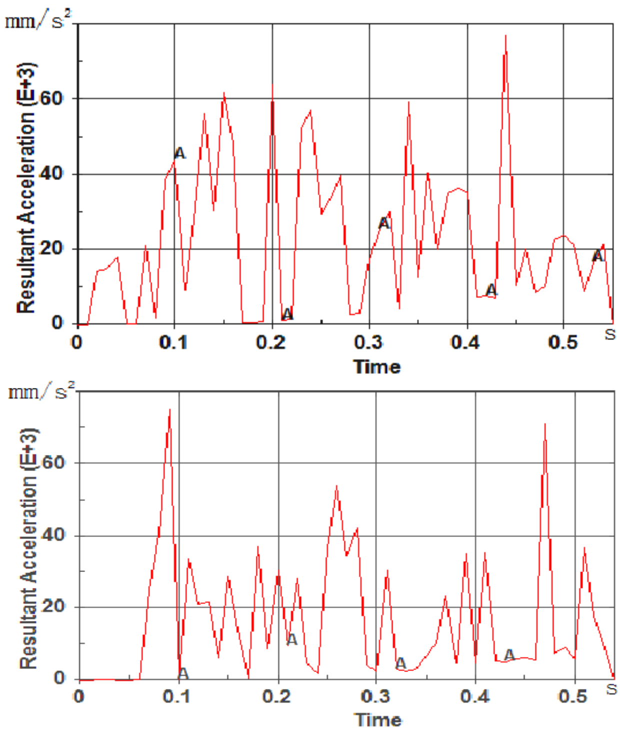

FIG. 5 THE ACCELERATING HISTORY CURVE FOR 5M, 7M COLUMN SPACING RESPECTIVELY

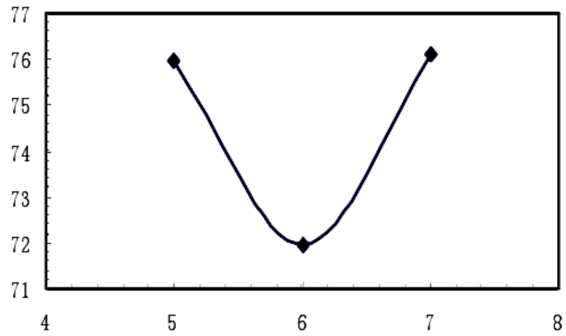

FIG. 6 THE ACCELERATION EXTREME TREND CURVE OF DIFFERENT COLUMNS SPACING

3) *Contrast Analysis of the Contact Force*

It is seen from Fig. 7 that, with the increase of the spacing of the stand column, the crash force decreases, and the effect is obvious. The instantaneous maximum value of the contact force under 5 m spacing is 144 kN; the maximum value under 6 m spacing is 130.2 kN; the maximum value under 7 m spacing is 111.2 kN; when it is varied from 5 m to 7 m, the range ability of the contact force has already passed 28.6%.

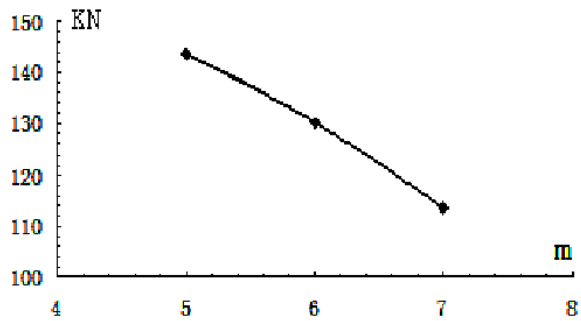

FIG. 7 THE CONTACT FORCE TREND CURVE OF DIFFERENT COLUMNS SPACING

4) *Contrast Analysis of the Breakdown Case*

For breakdown cases of the barrier under different spacing of the stand column, its breakdown forms are as TABLE 2.

TABLE 2 THE GUARD BAR DAMAGE SHEET OF VARIOUS COLUMN SPACING

distance between two columns (m)	5	6	7
Maximum displacement (mm)	265.3	75.3	19.6
Maximum tension (kN)	161.2	135.9	121.5

As shown in the above table, the maximum lateral displacement on the top of the second stand column behind the crash point under 5 m spacing has already reached 26.3 mm, while under 6 m, 7 m spacing, that are 75.3 mm, 19.6 mm, so the stand column can be considered to be undamaged. Accordingly, it can be considered: smaller the spacing of the stand column, the more remarkable the damage. However, it does mean that the larger spacing is better. If the spacing is larger, the dynamic deformation of the barrier is larger, and the requirement of the roadside clear width is higher.

It can also be seen in the table above that, when the spacing of the stand column is 5 m, the maximum tension of the cable is 161.2 kN, which is larger than the breakdown tension of the cable, 160.8 kN, and the cable will break down.

Hence, for given initial tension and installation length, larger spacing of the stand column of the cable is not better. When the spacing of the stand column is 6 m, the safety performance of the cable barrier is relatively more superior.

Conclusion

To sum up, it is considered in the analysis: the effect of the spacing of the stand column on the cable barrier is significant. When the initial installation tension and the installation length are determined, and its spacing of the stand column is 6 m, the safety performance of the barrier structure is relatively superior. In the case that the clear width of the roadside meets the requirement, it is reasonable that the initial tension of the cable barrier is between 30 kN and 35 kN. For the installation length, above a certain installation length, the effect of its change is relatively small. Analytical results can be referred by the design.

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